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Distribution and abundance indices of marine mammals in the Gully and two adjacent canyons of the Scotian Shelf before and during nearby hydrocarbon seismic exploration programmes in April and July 2003

Distribution et indices d'abondance des mammifères marins dans le Goulet et deux canyons adjacents du plateau néo-écossais avant et pendant des programmes d'exploration sismiques voisins en avril et juillet 2003

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ABSTRACT

The Sable Island Gully is a submarine canyon on the eastern Scotian Shelf that provides habitat to a wide diversity of species including the endangered northern bottlenose whale (*Hyperoodon ampullatus*). Seismic surveys for hydrocarbons were conducted in waters adjacent to the Gully in the spring and summer of 2003. An effort to evaluate marine mammal species composition, distribution, and abundance within the Gully prior to, and during these seismic surveys was coordinated by the Centre for Offshore Oil and Gas Environmental Research (COOGER). Vessel-based line transect surveys were conducted in the Gully over areas of 1565 km^2 and 2218 km^2 before and during seismic operations and over an area of 1851 km^2 covering two adjacent marine canyons (Shortland and Haldimand Canyons) only before seismic activities. Visual detections were accomplished by a team of two observers and a recorder from a location 7 m above the sea aboard a research vessel, 37 m in length, following a saw-tooth transect design at 18.5 km/h. In the Gully, 148 km were surveyed on 30 April prior to seismic data acquisition, and a total of 395 km were surveyed on 8, 10 and 11 July while seismic operations were underway. In the Shortland and Haldimand Canyons, 175 km of lines were surveyed on 1 May. Seven species of marine mammals in 45 groups (84 individuals) were identified in both areas in spring, with northern bottlenose whale being the most abundant of detected species with three groups (13 individuals) in the Gully and one group (5 individuals) in Shortland Canyon. In July, 11 species in 207 groups (563 individuals) were identified in the Gully, where northern bottlenose whales (8 groups, 35 individuals) were outnumbered by common dolphins (*Delphinus delphis*), pilot whales (*Globicephala* sp.) and grey seals (*Halichoerus grypus*). Four species of large whales were identified during the surveys, with fin (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*) detected in both spring and summer, and blue (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) detected only in summer. Estimated abundance, not corrected for animals missed on the track-line (*i.e.* g(0)=1), of northern bottlenose whales in the Gully were 44 (95%CI: 19–105) in April and 63 (95% CI: 20–230) in July. Fin, humpback, sperm and blue whales, combined into a large whale category for the Gully, were estimated to number 89 (95% CI: 31-254) in April and 114 (95% CI: 61-214) in July. Abundance in the Gully of common, Atlantic white-sided (*Lagenorhynchus acutus*), bottlenose dolphins (*Tursiops truncatus*), and harbour porpoises (*Phocoena phocoena*), combined as one group, was estimated at 121 (95% CI: 21–686) in April and 1763 (95% CI: 849-3659) in July. Changes in composition, distribution and abundance of marine mammal species between the spring and the summer surveys most likely represent seasonal variation rather than an effect of seismic activity. Since we had to use a uniform model for density estimation of northern bottlenose whales, and did not correct for sighting availability and detection on the track-line for any species, the densities and abundances presented here are likely underestimated.

RÉSUMÉ

Le Goulet de l'Île de Sable est un canyon sous-marin de l'est du plateau néo-écossais qui procure un habitat pour une large diversité d'espèces dont la baleine à bec commune (*Hyperoodon ampullatus*) qui est en danger de disparition. Des relevés sismiques pour des hydrocarbures ont été réalisés dans les eaux adjacentes au Goulet au printemps et à l'été 2003. Un effort pour estimer la composition, la distribution et l'abondance des espèces présentes dans le Goulet avant et pendant ces relevés sismiques a été coordonné par le Centre de Recherche Environnementale sur le Pétrole et le Gaz Extracôtiers (CREPGE). Des relevés en ligne à bord d'un bateau ont été effectués dans le Goulet sur des zones de 1565 km^2 et 2218 km^2 avant et pendant les relevés sismiques et sur une zone de 1851 km^2 recouvrant deux canyons sous-marins voisins (canyons Shortland et Haldimand) seulement avant les activités sismiques. Les détections visuelles étaient assurées par une équipe de deux observateurs et d'un enregistreur d'une position située à 7 m au-dessus de la mer, sur un bateau de 37 m suivant des transects en dents de scie à une vitesse de 18.5 km/h. Dans le Goulet, 148 km de transects ont été couverts le 30 avril avant les relevés sismiques, et un total de 395 km ont été couverts les 8, 10 et 11 juillet pendant les relevés sismiques. Dans les canyons Shortland et Haldimand, 175 km de transects ont été couverts le 1 mai. Sept espèces de mammifères marins en 45 groupes (84 individus) ont été identifiées dans l'ensemble des régions au printemps, dont des baleines à bec communes qui représentaient la plus abondante des ces espèces avec 3 groupes (13 individus) dans le Goulet et un groupe (5 individus) dans le canyon Shortland. En juillet, 11 espèces en 207 groupes (563 individus) ont été identifiées dans le Goulet, où les baleines à bec communes (8 groupes, 35 individus) étaient dépassées en nombre par les dauphins communs (*Delphinus delphis*), les globicéphales (*Globicephala* sp.), et les phoques gris (*Halicheorus grypus*). Quatres espèces de grandes baleines ont été identifiées pendant les relevés, soit le rorqual commun (*Balaenoptera physalus*) et le cachalot (*Physeter macrocephalus*) observés au printemps et en été, ainsi que le rorqual bleu (*Balaenoptera musculus*) et le rorqual à bosse (*Megaptera novaeangliae*) observés seulement en été. Les estimations d'abondance de baleines à bec commune dans le Goulet, non-corrigées pour les animaux manqués sur la ligne (*i.e.* g(0)=1), étaient de 44 (IC 95% : 19-105) en avril et de 63 (IC 95% : 20-230) en juillet. Les rorquals communs, rorquals à bosse, les cachalots et les rorquals bleus, regroupés comme grandes baleines, furent estimés à 89 (I.C. 95% : 31-254) en avril et à 114 (I.C. 95% : 61-214) en juillet dans le Goulet. L'abondance dans le Goulet des dauphins communs, à flancs blancs de l'Atlantique (*Lagenorhychus acutus*), grands dauphins (*Tursiops truncatus*) et les marsouins communs (*Phocoena phocoena*), considérés comme un groupe, était de 121 (I.C. 95% : 21-686) en avril et de 1763 (I.C. 95% : 849-3659) en juillet. Les changements de la composition, de la distribution et de l'abondance des espèces de mammifères marins entre les relevés de printemps et d'été représentent vraisemblablement des changements saisonniers plutôt qu'un effet de l'activité sismique. Comme nous avons utilisé un modèle uniforme pour l'estimation de densité des baleines à bec communes, et que nous n'avons utilisé aucun facteur de correction pour la disponibilité et la détection sur la ligne pour aucune des espèces, les densités et abondances présentées dans ce document sont probablement des sous-estimations.

INTRODUCTION

The Gully has been proposed as a Marine Protected Area because of its species complement, particularly members of the endangered Scotian Shelf population of northern bottlenose whales (hereafter referred to as NBW). From photo-identification work conducted in summer months from 1988 to 1999, the NBW population frequenting the Gully was estimated to number 133 animals (95% CI: 111–166), with approximately 34 % of this population being present in the Gully at any given time (Hooker *et al.* 2002).

The offshore seismic exploration programmes proposed to occur in the spring and summer of 2003 within 10 km of recognised NBW habitat in the Gully, Shortland and Haldimand Canyons,(Gowans *et al.* 2000; Whitehead *et al.* 1997; Wimmer 2003), elicited concerns about the potential impacts of these activities on this endangered species and other marine mammals present in these canyon structures. Two programmes of seismic exploration for hydrocarbon reserves were conducted in areas adjacent to the three canyons in summer 2003. EnCana Corporation (vessel: *Geco Triton*, Western Geco) conducted a 3-D seismic survey in a 1734 km^2 area on the shelf slope about 10 km to the east of the center of Haldimand Canyon from 3 May to 28 June 2003. Marathon Canada Ltd (vessel: *Ramform Viking*, Petroleum Geo-Services) conducted a 3-D seismic survey in a 2160 km^2 area adjacent (0.8 km away) to the south-west limits of the Gully marine protected area from 20 June to 15 October 2003. Airgun sounds can propagate horizontally, and the size of the area thus ensonified around the seismic array depends on the physical characteristics of the sound source (e.g., size and configuration of array), and the physical characteristics of the environment (e.g., water density, bathymetric features, bottom composition). To evaluate potential effects of seismic surveys on marine mammals in the Gully, the first step is to collect baseline and post-exposure information on species composition, distribution, and vertical location in the water column. When combined with *in situ* measurements of sound levels and sound propagation models, the levels of seismic sound to which individuals of different species will be exposed can be estimated. Further, it was assumed that if changes in the abundance or distribution of marine mammals in the Gully were detected that exceeded survey estimate variation or expected seasonal variation, these changes might be attributable to exposure to seismic sounds.

Fully evaluating the effects of seismic exploration on marine mammals requires an extensive research programme that involves collection of information on the species composition of the area, the distribution and activity of animals and their prey (possibly using instrumented study animals), and knowledge of the behavioural and physiological effects of sound levels to which the study animals are exposed (*e.g.* Croll *et al.* 2001). During spring and summer 2003, a pilot study was initiated to (1) obtain baseline information on the species composition, abundance, and distribution of marine mammals in the Gully and adjacent canyons, and (2) to estimate the ambient and seismic-related sound levels within the Gully prior to and during the seismic exploration programme. This project was part of a larger programme coordinated by COOGER that also included projects on near and far field sound level measurements, marine mammal vocalisation analyses, marine mammal observations from seismic survey vessels. This paper reports information on distribution, abundance and species composition of the marine mammal fauna in the Gully and in two adjacent canyons (Shortland and Haldimand).

METHODS

Survey Design

Distribution and abundance of marine mammals within the Gully, Haldimand and Shortland Canyons were estimated using data collected during ship-based visual line-transect surveys conducted prior to (27 April to 2 May 2003) and during (4 to 16 July 2003) seismic exploration conducted in adjacent areas of the Scotian Shelf. The surveys were conducted from a 37 m long vessel, the *Strait Signet* (Superport Marine, Port Hawkesbury, Nova Scotia), during missions where the primary goal was to collect acoustic recordings of seismic sounds and marine mammal vocalisations.

The survey design was planned to sample two areas of 1851 km^2 (55.6 km × 33.3 km). The first area was centered on the Gully and covered the region considered to be the most important for NBWs. The second area covered both Shortland and Haldimand Canyons. The transects covered both areas with five lines in a saw-tooth design for a total of 175 km (see Appendix 1 for details). To reduce the problem of over-sampling in corners and dependence between adjacent lines in such a saw-tooth design, the lines in Gully were placed so that each covered most of the range of bathymetric gradient, and were centered on (with both ends extending outside) the area recognised as preferred NBW habitat. The lines in Shortland and Haldimand Canyons area were centered on the 1000 m isobath which corresponded to the steep slope canyon features and roughly the preferred depth range for NBWs in the Gully (*i.e.*, 1000 m to 1500 m, Hooker *et al.* 2002). The survey speed was 18.5 km/h so that a set of five lines could be surveyed during daylight hours in one day.

Observation Protocol

A team of three experienced observers moved every half hour during the survey through two observer and one recorder stations. The observation platform was on top of the wheelhouse, 7 m above sea level (observer eye height ≈ 8.7 m), and sightability was 360° around the vessel for both observer stations combined. Scanning was primarily done by naked eye in a 180° arc in front of the vessel, with the port and starboard observers searching 100° sectors which overlapped 20° in front of the vessel. All observers had previous experience with marine mammal surveys and received additional training on sampling protocol and species identification prior to the survey.

Vessel position, weather conditions, and sighting information were recorded on a palm computer (Allegro Field PC, Juniper Systems, Logan, Utah) synchronised with GPS time and positions recorded every 30 sec to mapping software (Fugawi, Toronto, Ontario) during the spring mission. In July, all data were recorded using a dedicated survey programme (VOR, National Marine Fisheries Service, Woods Hole, Mass.) on a laptop linked to a GPS (Garmin). Weather conditions were recorded every half hour or before when changes in conditions noticeably affected visibility. Recorded weather parameters included: sea state (Beaufort scale), wave and swell height and direction, cloud cover in eighths, the relative bearing of glare reflection, angle of sighting affected, intensity of reflection, the presence of rain or fog, and distance of visibility (NM). Radial distance, relative bearing from the track-line, group size, and species were recorded for each sighting. Radial distance was estimated using one of three methods, here in preferred order: (1) 7 × 50 binoculars equipped with reticules, (2) measurement of the angle below the horizontal using an inclinometer, or (3) estimated by eye for small and fast-swimming animals within 100 m of the vessel. The inclinometer was used when sightings were too close to the boat to have the horizon and the sighting in the field of view of the 7x50 binoculars. Estimated measurements were used when animals close to the boat broke the surface too rapidly to allow the use of the two measuring instruments. Reticule or inclinometer angles were converted to distance using formulae considering the curvature of the Earth (Lerczak and Hobbs 1998). Perpendicular distance from the track-line was then calculated as the radial distance multiplied by the sine of relative bearing of sighting measured using a pelorus (*i.e.*, angleboard). High-power binoculars (25 × 150, Fuginon) were also used to estimate group size and for species identification, but the movement of the platform prevented their use as a primary searching method. Behaviour, sighting cue, swim direction and reaction to vessel were also recorded. When NBWs were close to the vessel, usually during extended stops at acoustic recording stations rather than during the survey transects, observers obtained high-resolution digital photographs of the whales' heads, dorsal fins, and flanks using Nikon D1H cameras with AF Nikkor 80-200mm 2.8 zoom lenses. An experienced researcher (T. Wimmer) compared the shapes and sizes of scars and colour patterns on these NBW photographs with those in existing images in a catalogue maintained at the Hal Whitehead Laboratory at Dalhousie University, Halifax, Nova Scotia.

Analysis

Detection function model and effective strip width (ESW) were estimated using the software Distance 4.1 on ungrouped perpendicular distances of groups of individuals (Thomas *et al.* 2003; Buckland *et al.* 2001). Detection curves were estimated for large whales, dolphins, and for each species not included in these two categories of species with similar detectability (*e.g.*, size and surface cues). The large whale

category included blue, fin, humpback, and sperm whales, and all large blows that could not be identified to species. The dolphin category included common, Atlantic white-sided, and bottlenose dolphins, harbour porpoises and small cetaceans identified as porpoises or dolphins.

Line transect estimation is based on three principal assumptions: (1) all animals on the track-line are detected, (2) the animals are detected at their initial location before any reaction to the observer and (3) distances from the track-line are measured accurately. Correction factors, referred to as g(0) correction factors can be applied to density estimation to account for animals that were diving when the boat covered the area and to correct for the proportion of animals at the surface that might have been missed by observers. The estimation of density and abundance presented here did not include such a correction factor and should therefore be considered as indices. Distributions of perpendicular distances were examined to detect evidence of movement and aggregation around zero. Rounding of measurements was evaluated from frequency distributions of measured variables (*i.e.*, relative bearing, reticule angle, inclinometer angle and estimated distances). Single observations away from the bulk of sightings were truncated and the modified dataset was only used for analysis if truncation improved the fit and consistency between different detection models. The best of three key functions available in Distance (Uniform, half-normal and hazard-rate) was selected using Akaike's Information Criteria (AIC), which selects the model that best fit the observation data, but includes a penalty for the number of parameters in the models. Adjustment terms were only added if no key function provided a suitable detection function. Post-stratification by season (spring and summer) and by cue (blow, splash, body) was examined using the best model and used if the sum of AIC of post-stratified detection curves was lower than the AIC value for a detection function of the pooled dataset.

The dependence of cluster size on perpendicular distance was evaluated using the regression of natural logarithm of group size ($\ln(s_i)$) on the probability of detection ($g(x)$), which when significant ($p<0.15$), provided an expected cluster size at maximum detectability (*i.e.* nearest perpendicular distance).

Density and abundance indices of species in each of the three strata, Gully in spring, Gully in summer and Shortland-Haldimand in spring, were calculated using the overall or stratum detection function applied to the specific number of sightings and expected group size in each stratum. Encounter rate was estimated for each stratum and variance estimated empirically using lines as sampling units. Density, abundance and the Satterthwaite's 95% confidence intervals which includes a correction for small sample sizes for detection curve, expected cluster size and encounter rate, were estimated from formulae of Buckland *et al.* (2001). All density and abundance indices are for animals at the surface when the survey was conducted, and do not include availability corrections for whales missed because they were diving (availability bias) or overlooked (perception bias) by observers.

The Gully was surveyed over three days in the summer. The sightings of the 8 July were only used along with those of other days to select the overall detection model, but except for species that were only seen on that day (one blue whale and one fin or sei whale), the data were not used to estimate encounter rate for the entire period as this survey covered only the southernmost line. Summer density in the Gully was therefore averaged for 10 and 11 July and weighted by survey effort each day (see section 3.7 in Buckland *et al.* 2001).

RESULTS

Survey Conditions

Two days of systematic surveys were done in spring before seismic activity. Surveys were completed between 0645 and 1939, local time. Wind was the limiting factor with sea states suitable for surveys (Beaufort <4) encountered during two days out of four at sea. One set of five lines equalling 175 km were surveyed in the planned 1851 km^2 stratum of the Shortland and Haldimand Canyon on 1 May. Of the planned survey design of 175 km, the team completed 148.4 km in the Gully on 30 April, which covered a rectangular area of 1565 km^2 (Figure 1).

Only the Gully area was covered by systematic survey in July. Surveys were completed between 0654 and 2049 local time. Fog was the primary restriction for the survey, limiting visibility on seven of 11 days at sea. A total of 395.4 km of lines was surveyed over the 8, 10 and 11 July (Figure 2). Only 27.2 km of the southernmost line was covered on the 8th, and the northernmost line could not be completed on the 11th, for a total of 158.2 km that day. A sixth line was added to the north of the survey area for 210 km of lines on the 10th, and that rectangular area surveyed was 2218 km^2. Sea state conditions were more favourable in summer than in spring with conditions above Beaufort 3 for only part of the day on 11 July (lines 4 and 5).

Marine Mammals Sighted

Marine mammal sightings in the Gully were less frequent and less diverse in spring than in summer, with seven marine mammal species sighted in the Gully and the Shortland-Haldimand areas. These animals were distributed in 25 groups for a total of 53 individuals in the Gully, and in 20 groups for a total of 31 individuals in the Shortland-Haldimand area (Figure 1). The eleven species identified in the Gully in summer were distributed in 207 sighting events for a total of 563 individuals (Figure 2).

Northern bottlenose whales, fin whales and sperm whales were the only three large whale species that were detected in both spring and summer, while blue and humpback whales were only detected in summer. Two blue whales were seen in transit between recording stations. One of these did not match any previously-identified individual in an existing catalogue (Richard Sears, MICS), and is thus an addition to the small Atlantic blue whale population.

(1) Northern Bottlenose Whales

Twelve groups of NBWs were detected with one group of five animals seen in the Shortland Canyon on 1 May during a day of survey outside of the Gully. This species has been previously associated with environments of water depth of 1000-1500 m (Hooker *et al.* 2002). Five out of 12 groups were detected in that depth range with exceptions detected in waters shallower than 800 m (3/4 groups) in spring and in waters deeper than 1900 m in summer (4/8 groups) (Figures 1 and 2).

Twelve groups of NBWs were detected up to 1550 m from the track-line (Figure 3). The detection function was estimated using the untruncated dataset pooled over all strata for which the best model was uniform (AIC=176.3). The modelled uniform detection probability of one represents the largest ESW possible, which is equivalent to a strip transect where width is determined by the largest perpendicular distance recorded, *i.e.* 1552 m (Figure 3). With this model, the eight NBWs detected on 30 April, and the 29 detected on 10 and 11 July, were used to provide abundance indices for the Gully of 44 whales (95% CI: 19–105 whales) and 68 whales (95% CI: 20-230 whales), respectively (Table 1).

These results can be treated as a pilot survey to estimate the total length of survey lines required to produce a density estimate with a target precision (e.g., CV of 20%, see 7.2.2 in Buckland *et al.* 2001). Given the eight groups detected over 395.4 km of lines surveyed in the Gully in July, a total of 2966-3954 km of lines would be required to provide the 60-80 observations that are assumed necessary to produce

a reliable detection model. These efforts would then provide abundance indices with CVs of 22% and 19%, respectively.

The NBWs did not appear to react to the survey vessel, but approached and circled the vessel when it was stopped at two acoustic recording stations within the Gully. The whales' respiration rates and surfacing frequencies were similar during our observations made during seismic operation to whale behaviour video recorded in the Gully previously by Whitehead's research team, and to video of NBWs taken off Labrador. After comparing the digital photographic records of NBW taken during the project with identified whales for the Gully, 9 whales were uniquely identifiable and properly photographed, and of these, one already existed in the Whitehead NBW Gully catalogue. Of the remaining 8 individuals, 4 had markings but photographs were of poor quality and 4 had no obvious permanent markings, it is unlikely these whales can be matched to individuals in the catalogue.

(2) Large Whales

Four species of large whales were identified and detected in 52 groups. Only fin and sperm whales were identified in spring. Fin whales were detected in four groups (nine animals) in the Gully and in three groups (five animals) over the shelf in the Shortland Haldimand area (Figure 1). Two single sperm whales were detected at the head of the Shortland Canyon in waters 300 to 400 m in depth. These two species were still present in similar numbers in the Gully in July with five groups or seven fin whales and one pair of sperm whales. The seven humpbacks and one blue whale were seen only in July.

Sightings of large whales, detected in spring and summer, were combined for model selection. The distribution of perpendicular distances suggested truncation at 3353m, excluding two sightings estimated to be at 8.3 km and 9.1 km from the track-line. The distributions of recorded relative bearing, reticule readings, inclinometer angles, estimated distances and perpendicular distances did not suggest failure of assumptions such as rounding of measurements by the observers or movement away from the vessel (Figure 4). The hazard-rate model (AIC=751.6) for the remaining 49 groups of large whales provided an ESW of 951 m (95% CI: 621–1456 m). Model selection was not improved by season stratification (sum of AICs=754.7) nor by cue stratification (pooled body and blow AIC=677.4, sum of stratified AICs=675.6). No cluster size bias was detected from the regression of the pooled natural logarithm of cluster size (ln(s)) over detection function ($g_{(x)}$) (T=0.36, *df*=47, *p*=0.64), and therefore mean cluster size per stratum was used for specific density and abundance indices (Table 1).

The numbers of groups of each species of large whale detected within each stratum only varied from one to four for a given day. Although fin whales might have been considered the most consistently detected species, with daily detections of two to four groups, such infrequent sightings and large coefficients of variation (CV 45% to 102%, Table 1) could not detect any difference in density or abundance indices between strata.

Only one blue whale and one animal identified as either a fin or sei whale were detected on transect on 8 July. Assuming a similar distribution of density for these species as for all other large whale species (*i.e.* similar encounter rate CV), density of blue whales in summer for the three days of survey would be 0.0013 (CV=1.02; 95% CI: 0.0002–0.0076), for a corresponding abundance index of three (95% CI: 1–17).

(3) Dolphins (Small Odontocetes)

We use the term "dolphin" for this group in the next sections even though it might be more properly referred to as "small odontocetes", as this group includes harbour porpoises along with common, Atlantic white-sided and bottlenose dolphins. Seventy-two groups of dolphins were detected during spring and summer, but species composition varied between the two missions. Although the effort was greater and sea state lower in the Gully in summer, the eight groups of harbour porpoises identified were detected in spring, in water equal to or shallower than 200 m (Figure 1). Except for two groups of unidentified dolphins in spring, dolphin species were seen only in summer. Common dolphins were seen at the mouth and at the head of the Gully as defined by the 200 m isobath. The 13 white-sided dolphins, seen in two

groups, were detected at the mouth of the Gully and the group of 12 bottlenose dolphin was seen on Sable Island Bank (Figure 2).

The distribution of perpendicular distances of dolphins revealed one peak on the track-line, and a second between 300 and 400 m suggesting that there might have been movement either towards or away from the vessel at close range as has been reported for dolphins elsewhere (Figure 5, e.g., Würsig *et al.* 1998). Some groups were obviously moving towards the vessel to bow ride, and it is possible that reaction to the vessel affected their location prior to their initial detection by observers. The distribution of initial swimming direction of dolphins relative to the bearing from the vessel to their location, shows that most of the detections are made when dolphins were swimming perpendicularly to the detection angle (Figure 6). This suggests they were easier to sight when exposing their body side to observers, rather than an indication of movement towards or away from the vessel. The fast movement of dolphins and reaction to the vessel could be a potential bias in the abundance estimation.

Dolphins were detected up to 1.9 km from the track-line, but the only three observations beyond 1178 m were truncated. The hazard-rate was the best model for the remaining 67 perpendicular distances (AIC=905.4) and was used for dolphin density estimation. Model selection was not improved by stratification by season (spring + summer AICs=905.3) nor by cues (splash + body AICs=817.1; AIC pooled for 60 observations with cues=814.3). The pooled model provided an ESW of 523 m (95% CI: 402–680 m). There was no relationship between the natural logarithm of cluster size and detection probability (T=-0.46, *df*=62, *p*=0.32), therefore mean cluster size was used within each stratum for density estimation (Table 1).

Since they all used the same detection curve, the only difference in dolphin species abundance between strata was the expression of different encounter rates and expected cluster sizes. The most obvious difference comes from species composition between season, with harbour porpoises only identified in spring in both the Gully and the Haldimand Shortland area, and never identified in summer when sea states were lower and overall small odontocetes density was higher. Of the three species of dolphins present in the Gully in summer, common dolphins were the most abundant, and the most prevalent of all cetaceans.

(4) Minke Whales

Thirty-five minke whales were detected during the spring and summer surveys. Three animals were seen in Shortland Canyon, and one in the Gully in spring (Figure 1). Eighteen of the 29 minke whales seen in summer were sighted in water depths of less than 200 m over the eastern Sable Island Bank (Figure 2).

Minke whales were detected up to 1142 m from the track-line and always alone. The distribution of the 33 recorded perpendicular distances suggest some heaping at 0 m, below 400 m and 750 m, but examination of relative bearing, reticule measurements, angles from inclinometer and estimated distances does not reveal any signs of rounding that would have indicated recording errors, so data were treated as recorded without any transformation or grouping. Truncation was done at 767 m to eliminate one observation at 1142 m. For the remaining 32 minke whales detected in spring and summer, the hazard-rate was the best model (AIC=378.5). No post-stratification by cue could be done as only the 25 minke whales detected when their body broke the surface provided enough data to estimate a model. Model selection was improved by post-stratification by season (sum of AICs=375.5), which revealed that the four spring minke whales were detected closer to the track-line than what would have been expected from the summer-based distribution of perpendicular distances (Figure 7). The seasonal detection functions provided an ESW of 58 m (95% CI: 3–1112 m) in spring and 383 m (95% CI: 157–936 m) in summer.

The narrower detection function in spring than in summer suggested that searching for minke whales might not have been as effective during the first mission. This might be due to the higher sea states in spring, but this did not affect detection of other species. Encounter rates were also smaller for both geographic strata in spring than in the Gully in summer which compensated for the narrower strip with in estimation of density and abundance. However, the low number of observations for the detection func-

tion and the lower encounter rates in spring increased the variance associated with the estimation of each of these components. This resulted in an abundance estimate of 91 (95% CI: 9–923) in the Gully in April that was lower and not as precise as the July abundance estimate of 236 minke whales (95% CI: 83–668).

(5) Pilot Whales

One group of four pilot whales was detected in spring and 14 groups were detected in summer. They were seen from the north to the south of the Gully with seven groups seen at the mouth of the Gully as defined by the 2000 m isobath (Figures 1 and 2).

The detection curve was estimated using data from 13 groups, which ranged out to 1002 m from the track-line. The untruncated perpendicular distances were used because the number of observations was limited and no obvious outliers were present. As for NBWs, the best model was uniform (AIC=179.7), which provided an ESW of 1002 m. No post-stratification by season nor cue could be tested because 12 of the 13 sightings were detected in summer and 11 of the sightings were detected by their bodies, with only one blow and one splash being seen. Pilot whales in the Gully were less abundant on 30 April with 21 whales (95% CI: 2–179) than they were in July with 228, 95% CI: 65–804). This difference was due to the presence of more groups in July, as revealed by higher encounter rates, rather than to a difference in group size (Table 1).

(6) Grey Seals

Grey seals were more numerous in Gully waters in summer with 68 groups and 93 individuals, than in spring when only three individuals were detected on 30 April. All grey seals were detected in waters equal to or shallower than 200 m, and 62 groups (91% of summer groups) were detected on the eastern Sable Island Bank in summer (Figures 1 and 2).

As priority was given to observing cetaceans, distance measurements were recorded for 45 of the 73 groups of grey seals detected. Maximum perpendicular distance was 376 m. Truncation at 260 m left 44 observations from which hazard-rate was selected as the best model (AIC=481.1). The five groups detected in spring might not have followed a similar distribution as in summer and detection function was estimated independently for seasons (sum of AICs=479.6). The ESW was 86 m (95% CI: 19–387 m) and 113 m (95% CI: 58–217 m) for spring and summer, respectively.

All grey seals detected in spring were single animals and there was no dependence of the natural logarithm of cluster size with detection probability in summer ($T=0.041$, $df=37$, $p=0.52$). Therefore, mean cluster size was used within each stratum for density estimation (Table 1). Grey seals were the most abundant species in the Gully in both April and July. The species increased in abundance from April to July with abundance estimates of 184 (95% CI: 24–1089) and 2462 (95% CI: 927–6540), respectively (Table 1).

DISCUSSION

This baseline study was the first systematic ship-based line-transect survey designed to collect information on the species composition, abundance and distribution of marine mammals in the Gully area. Originally, a more ambitious programme was conceived, to evaluate potential changes in composition, abundance, and distribution in relation to seismic exploration. The project was to be conducted in one mission covering a period immediately prior to seismic operations as a baseline study, and then continuing after seismic operations started, to reduce confounding factors related to seasonal biotic changes.

Due to technical problems in 2003, the onset of the seismic programme was delayed by weeks, resulting in a strong possibility that the difference in marine mammal species composition, distribution, and abundance between the two study periods is due to seasonal movements of the different species, as

previously reported through variation of cetacean abundance between summer months in the Gully (Gowans and Whitehead 1995, Hooker *et al.* 1999). Where possible, further studies to address the impact on distribution of marine mammals should be conducted over a short time frame, as originally planned for 2003. Furthermore, to reduce other confounding effects these studies should also include studies of control areas to estimate the importance of density estimation changes at different time scales, with and without the occurrence of seismic activity.

Despite the changes to the survey design, in general a greater number of marine mammals were detected in the Gully in summer even though seismic surveys had been conducted outside the Cully and other canyons since 3 May to the east (EnCana Corporation) and since the 20 June to the south-west (Marathon Canada Ltd). More specifically, numbers remained similar between the two missions for NBWs and for the large blue, fin and sperm whales, which are thought to have better hearing sensitivities in the lower frequency range where much of the seismic energy is contained, and where sound propagates well (Figure 10). These surveys show that these marine mammal species were present in the Gully when exposed to received seismic sound levels up to 145 dB re 1 µPa (rms). However, these visual surveys were conducted while Marathon was acquiring seismic data at the most distant end of their survey area relative to the Gully; no data on abundance and distribution of marine mammals within the Gully were collected when the seismic exploration was conducted at the proximal extremity of their seismic programme that ended three months later, on 15 October. At a range of 20 km, which corresponds to the distance between a location where NBW were sighted earlier in the summer and the closest approach of Marathon's seismic array to the Gully area, and with propagation conditions similar to what has been estimated for July, NBW and other marine mammals could have been exposed to sound levels of 155 to 157 dB re 1µPa (rms).

There appeared to be no relationship between the distribution of whales and acoustic isopleths obtained from the acoustic aspect of this project, but the acoustic and visual survey effort provided a small sample for evaluation. The acoustic sampling in spring produced a limited representation of the acoustic baseline information for the Gully, and as for marine mammal distribution, the apparent seasonal variation in ambient and seismic noise exposure could not be fully evaluated.

The seasonal differences in abundance of different marine mammal species in itself can be used to evaluate the possible efficiency of mitigation measures such as area or seasonal restrictions of potentially disturbing human activities. The results of this project, together with previous studies, indicate that these mitigation approaches might not be effective for NBWs as this species appears to always be present in the Gully area (Hooker *et al.* 1999). The different hearing capabilities of the species present should also be considered when seasonal or regional restrictions are proposed as mitigation measures. Larger odontocetes, such as the NBWs and sperm whales, use acoustic frequencies generally higher than the primary acoustic energy range of seismic sources. Therefore, although not yet studied using telemetered individuals or by a finer-scale survey effort, the potential impacts of seismic sounds on these toothed whales may be less than on the large mysticetes. Indirect or long-term effects of seismic sound exposure were not addressed in this study. For example, the potential effects of seismic sounds on squid, such as *Gonatus* sp. which are believed to be an important prey of NBW (Hooker *et al.* 2001), have yet to be studied in the Gully.

The abundance indices for NBW and for other species presented in this document are most likely underestimations of their real abundance in the Gully in spring and summer 2003. The numbers of NBWs were not sufficient to estimate the reduction in probability of detection with distance from the track-line. A higher number of sightings would have likely produced a narrower ESW than the uniform model, leading to a higher abundance index. For instance, the estimated ESW of 1552 m for NBWs, is larger than the 951 m estimated for large whales, so it is likely that the uniform model used in this study provided a conservative estimate of abundance of NBWs in the Gully. Nevertheless, these indices of 44 NBWs in spring and 68 in summer are similar to the 44 (SE=6) estimated to be present in the Gully at any given time derived from photo-identification techniques used previously (Gowans *et al.* 2000). However, our abundance indices of all species do not yet include a correction for missed whales on the track-line {g(0)} due to their diving behaviour and observer oversight. Such a correction to the NBW indices in this study, if we use a 0.96 proportion of animals detected on the track-line as has been estimated for Baird's beaked

whale and presumed to be similar for NBWs (see Barlow 1999, Hooker and Baird 1999), would yield abundance estimates of 46 for spring and 71 for summer. However, this 0.96 correction factor was estimated for observers using 25 × 150 ("big eyes") binoculars, and it is likely that our team, using unaided vision, would have detected a lower proportion of animals on the track-line, necessitating an even larger correction factor and further increasing the abundance estimates. Producing better abundance estimates of NBWs and other species would require a variety of approaches: (1) increased visual survey effort (including aerial methodologies) to reduce the large variance of abundance indices, and (2) further telemetry and behaviour modelling studies to produce more acceptable availability bias and perception bias correction factors.

This is the first systematic ship-based line-transect survey of the Gully. The time available for survey represents a relatively small effort due to weather conditions impacting visibility and sea state such that 60% of the days at sea (9/15) were not optimal for survey. Using this as a pilot survey for NBWs in the Gully, and given (1) the recorded encounter rates, (2) the 2966-3954 km of lines required to provide 60–80 sighting records, and (3) the expected abundance estimates with target CV of 22% and 19%, future surveys would require 160-213 h of suitable survey conditions for a vessel speed of 18.5 km/h. If this can only be conducted on 40% of the available ship time, then 400-534 h of ship time during daylight hours would be required if weather conditions were similar to what was experienced in 2003. Further Gully surveys could also be designed to concentrate survey effort in recognised "primary" NBW area. Different stratification could increase the effort in these "primary areas", which may lead to an increase in the number of sightings to develop suitable detection curves and a reduction of the variance associated with encounter rates that would provide more reliable and precise abundance estimates. One advantage of a systematic visual survey over previous photo-identification work used for abundance estimation is that it provides geographically-distributed effort datasets that can be more easily employed for NBW habitat use analysis using GIS applications.

Another way of improving abundance estimates, would be to increase the number of sightings through the efficiency of the observer team, by using high-power binoculars (25 × 150) as the primary search tool. If sightability was good and the sighting platform more stable than the *Strait Signet*, or sea state conditions better than they were in spring and July 2003, the use of "big eye" binoculars could likely increase the number of sightings. For example, we obtained an ESW of 951 m for large whales with a platform height of 7 m. The same binoculars used on a vessel platform 10 m above sea level in California resulted in an ESW of 1,437 m for large whales (Barlow 1995), representing a search area 1.5 times larger than we had in the Gully. This searching efficiency could have been increased further, by 11% in the same California example, with a second team of observers (Barlow 1995).

This project, when we include a minimal correction factor for animals not at the surface, provided seasonal abundance estimates of NBWs within the Gully of 46 in spring and 71 in summer that are considered to be underestimations of the real abundance. These values are similar or larger than an estimate based on photo-identification (Hooker *et al.* 2002). However, the precision of these estimates, based on four days of systematic survey, could be improved by increased effort. The fact that only 11% (1 of 9) of the uniquely identifiable NBWs could be matched with whales in the Gully catalogue suggests that further photo-identification efforts are warranted as a component of visual surveys.

This project was not a thorough assessment of the impact of seismic activity on marine mammal abundance in the Gully. Even though the importance of seasonal variation in density could not be evaluated, we found that the species of concern (northern bottlenose whales, mysticetes, and sperm whales) were still present in the Gully when exposed to sound levels of 145 dB re 1 µPa (rms), after seismic activities had been underway for several weeks. The information on effort, density and associated variance provided by this project, can be used to estimate the survey effort that would be required, through longer ship-time periods or more effective searching techniques, to better detect changes in abundance and distribution at the scale that are shown from these results. Changes in abundance and distribution from surveys such as this provide measures of change at a population scale. However, a study intended to more thoroughly assess the impacts of seismic operations or any other human activity on a marine mammal population should include the monitoring of whales equipped with satellite-linked transmitters,

time-depth-velocity-sound recorders or other telemetry devices to measure the more subtle changes in behaviour at an individual scale.

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Table 1. Density indices of Northern bottlenose whales and 10 species of marine mammals in the Gully on 30 April, 10 and 11 July and in the Shortland Haldimand area on 1 May 2003. Analyses were conducted using the software Distance 4.1. Abundance indices are based on 1851 km^2 for the Shortland Haldimand area and on 1565 km^2 and 2218 km^2 for the Gully in spring and summer respectively. Density and abundance indices are not corrected for availability (g(0)) to consider the proportion of animals not at the surface or overlooked while the vessel was passing.

Species	n Pooled n/stratum	Pooled ESW (CV)	Encounter rate (CV)	Expected cluster size (CV)	Density index (CV)	Abundance index (95% CI)
Northern bottlenose whale	**12**	**1552 (0)**				
Shortland / Haldimand (1 May)	1		0.006 (1.00)	5.0 (0)	0.009 (1.00)	17 (2–172)
Gully (30 April)	3		0.020 (0.32)	4.3 (0.15)	0.028 (0.36)	44 (19–105)
Gully July					0.031 (0.59)	68 (20–230)
10 July	*6*		*0.029 (0.68)*	*4.2 (0.27)*	*0.038 (0.74)*	*85 (18–412)*
11 July	*2*		*0.013 (0.94)*	*5.0 (0)*	*0.020 (0.94)*	*34 (4–309)*
Large whales	**49**	**951 (0.21)**				
Shortland / Haldimand (1 May)	8		0.046 (0.32)	1.5 (0.13)	0.036 (0.40)	67 (28-159)
Gully (30 April)	8		0.054 (0.38)	2.0 (0.25)	0.057 (0.51)	89 (31-254)
Gully July					0.051 (0.31)	114 (61–214)
10 July	*15*		*0.071 (0.25)*	*1.5 (0.09)*	*0.055 (0.34)*	*122 (61–245)*
11 July	*14*		*0.088 (0.42)*	*1.0 (0.00)*	*0.047 (0.47)*	*78 (26–232)*

Species	n Pooled n/stratum	Pooled ESW (CV)	Encounter rate (CV)	Expected cluster size (CV)	Density index (CV)	Abundance index (95% CI)
Fin whale						
Shortland / Haldimand (1 May)	3		0.017 (0.67)	1.7 (0.20)	0.015 (0.73)	28 (5–141)
Gully (30 April)	4		0.027 (0.38)	2.3 (0.42)	0.032 (0.61)	50 (14–179)
Gully July					0.010 (0.47)	22 (8-57)
10 July	*2*		*0.010 (0.63)*	*2.0 (0.00)*	*0.010 (0.67)*	*22 (5–97)*
11 July	*3*		*0.019 (0.49)*	*1.0 (0.00)*	*0.010 (0.54)*	*17 (5–58)*
Humpback whale						
Shortland / Haldimand (1 May)	0					
Gully (30 April)	0					
Gully July					0.010 (0.45)	22 (9–55)
10 July	*3*		*0.014 (0.45)*	*1.3 (0.25)*	*0.010 (0.56)*	*22 (7–71)*
11 July	*3*		*0.019 (0.61)*	*1.0 (0.00)*	*0.010 (0.65)*	*17 (4–77)*
Sperm whale						
Shortland / Haldimand (1 May)	2		0.011 (1.00)	1.0 (0.00)	0.006 (1.02)	11 (1–108)
Gully (30 April)	0					
Gully July					0.003 (1.02)	6 (1–53)
10 July	*1*		*0.005 (1.00)*	*2.0 (0.00)*	*0.005 (1.02)*	*11 (1–93)*
11 July	*0*					

Species	n Pooled n/stratum	Pooled ESW (CV)	Encounter rate (CV)	Expected cluster size (CV)	Density index (CV)	Abundance index (95% CI)
Dolphin Sp.	**32**	**523 (0.13)**				
Shortland / Haldimand (1 May)	4		0.023 (1.00)	1.5 (0.19)	0.032 (102.69)	61 (6–586)
Gully (30 April)	6		0.040 (0.72)	2.0 (0.22)	0.077 (0.76)	121 (21–686)
Gully July					0.795 (0.37)	1763 (849–3659)
10 July	*33*		*0.157 (0.33)*	*6.8 (0.24)*	*1.017 (0.43)*	*2256 (928–5484)*
11 July	*25*		*0.158 (0.55)*	*3.3 (0.13)*	*0.500 (0.58)*	*83 (209–3349)*
Common dolphin						
Shortland / Haldimand (1 May)	0					
Gully (30 April)	0					
Gully July					0.322 (0.43)	714 (297–1711)
10 July	*12*		*0.057 (0.47)*	*6.9 (0.21)*	*0.377 (0.53)*	*837 (266–2632)*
11 July	*11*		*0.070 (0.63)*	*3.7 (0.16)*	*0.248 (0.66)*	*414 (88–1950)*
White-sided dolphin						
Shortland / Haldimand (1 May)	0					
Gully (30 April)	0					
Gully July					0.036 (1.14)	81 (8–842)
10 July	*2*		*0.010 (1.00)*	*6.5 (0.69)*	*0.059 (1.00)*	*131 (11–1537)*
11 July	*1*		*0.006 (0.94)*	*1.0 (0.00)*	*0.006 (0.95)*	*10 (1–93)*

Species	n Pooled n/stratum	Pooled ESW (CV)	Encounter rate (CV)	Expected cluster size (CV)	Density index (CV)	Abundance index (95% CI)
Bottlenose dolphin						
Shortland / Haldimand (1 May)	0					
Gully (30 April)	0					
Gully July					0.031 (1.01)	69 (8–596)
10 July	*1*		*0.005 (1.00)*	*12 (0.00)*	*0.055 (1.00)*	*121 (14–1045)*
11 July	*0*					
Harbour porpoise						
Shortland / Haldimand (1 May)	4		0.023 (1.00)	1.5 (0.19)	0.033 (1.03)	61 (6–586)
Gully (30 April)	4		0.027 (0.64)	2.3 (0.28)	0.058 (0.71)	91 (19–442)
Gully July						
10 July	*0*					
11 July	*0*					
Minke whale	**32**	**236 (0.46)**				
Shortland / Haldimand (1 May)	3	58[a] (0.78)	0.017 (0.67)	1.0 (0.00)	0.148 (1.02)	274 (30–2495)
Gully (30 April)	1		0.007 (0.90)	1.0 (0.00)	0.058 (1.19)	91 (9–923)
Gully July		383[a] 0.45)			0.106 (0.54)	236 (83–668)
10 July	17		0.081 (0.49)	1.0 (0.00)	0.106 (0.67)	234 (64-859)
11 July	13		0.082 (0.27)	1.0 (0.00)	0.107 (0.52)	179 (65–496)

Species	n Pooled n/stratum	Pooled ESW (CV)	Encounter rate (CV)	Expected cluster size (CV)	Density index (CV)	Abundance index (95% CI)
Pilot whale	**13**	**1002 (0.00)**				
Shortland Haldimand (1 May)	0					
Gully (30 April)	1		0.007 (0.90)	4.0 (0.00)	0.013 (0.90)	21 (2–179)
Gully July					0.103 (0.57)	228 (65–804)
10 July	6		0.029 (0.52)	2.2 (0.22)	0.031 (0.56)	68 (20-236)
11 July	8		0.199 (0.59)	7.9 (0.34)	0.199 (0.68)	332 (77–1429)
Grey seal	5	86[a] (0.50)				
Shortland Haldimand (1 May)	2		0.011 (1.00)	1.0 (0.00)	0.066 (1.12)	123 (14–1089)
Gully (30 April)	3		0.020 (0.90)	1.0 (0.00)	0.117 (1.03)	184 (24–1384)
Gully July	39	113[a] (0.37)			1.110 (0.50)	2462 (927–6540)
10 July	47		0.224 (0.44)	1.5 (0.18)	1.502 (0.58)	3332 (1062–10 453)
11 July	20		0.126 (0.35)	1.1 (0.05)	0.590 (0.48)	987 (370–2634)

[a] Seasonal detection curves were used for estimations of density for minke whales and grey seals.

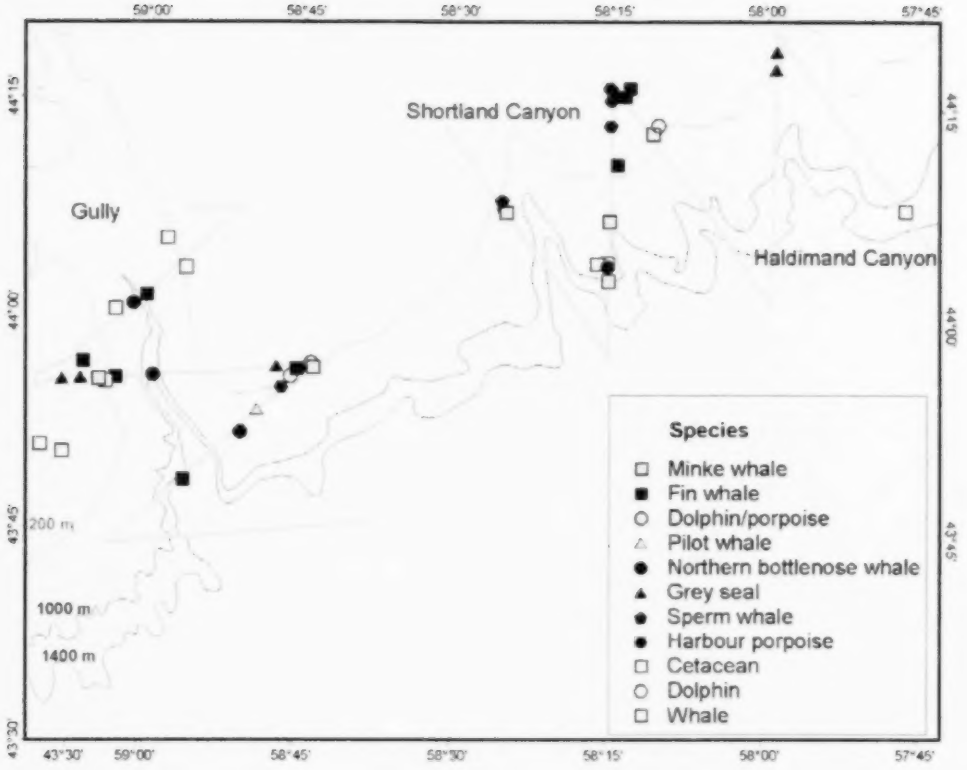

Figure 1. Distribution of all observations recorded during the baseline survey of 148 km of lines in the Gully on 30 April and of 175 km of lines in Shortland and Haldimand Canyons on 1 May 2003. Transects surveyed in the Gully, and in Shortland and Haldimand Canyons are shown by grey lines.

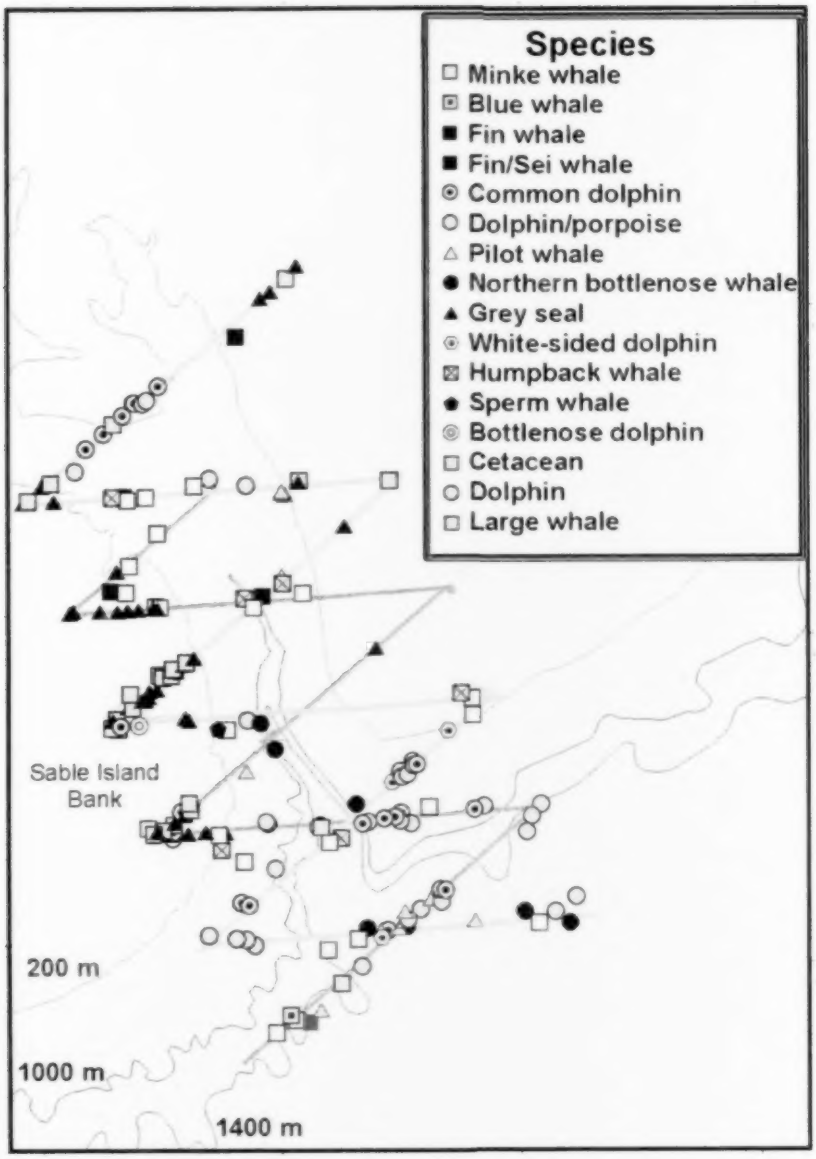

Figure 2. Distribution of all observations recorded along 395 km of lines covered over the 8, 10 and 11 July 2003 in the Gully area, while seismic operations were underway in an area 27 to 56 km to the southwest of the end of survey lines. Transects surveyed are shown by grey lines.

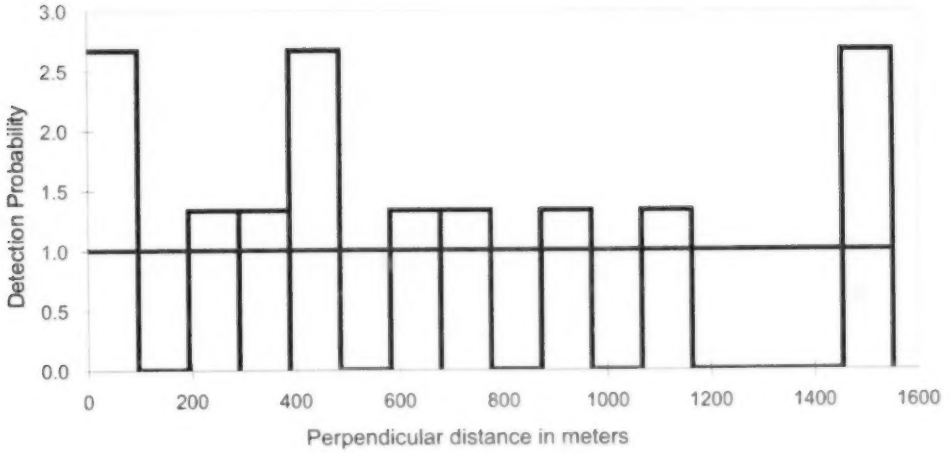

Figure 3. Distribution of the perpendicular distances from track-line for the 12 groups of northern bottlenose whales sighted during spring and summer, with the uniform detection curve providing an ESW of 1552 m, the maximum perpendicular distance.

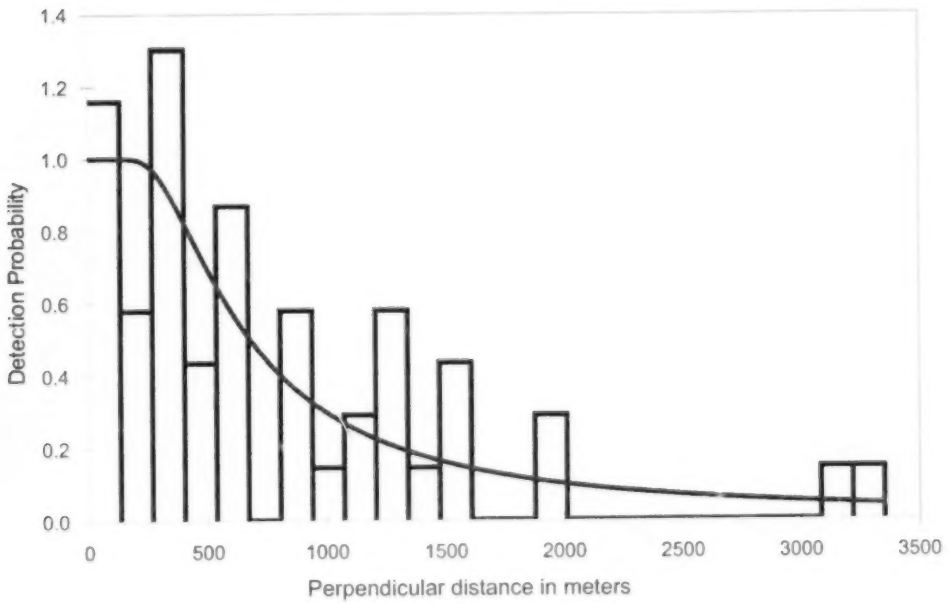

Figure 4. Distribution of all large whale (blue, fin, humpback, sperm and unidentified large whales) perpendicular distances from track-line during spring and summer, and the detection curve (hazard-rate) fitted on dataset truncated at 3353 m which provided an ESW of 951 m (95% CI: 621-1456 m).

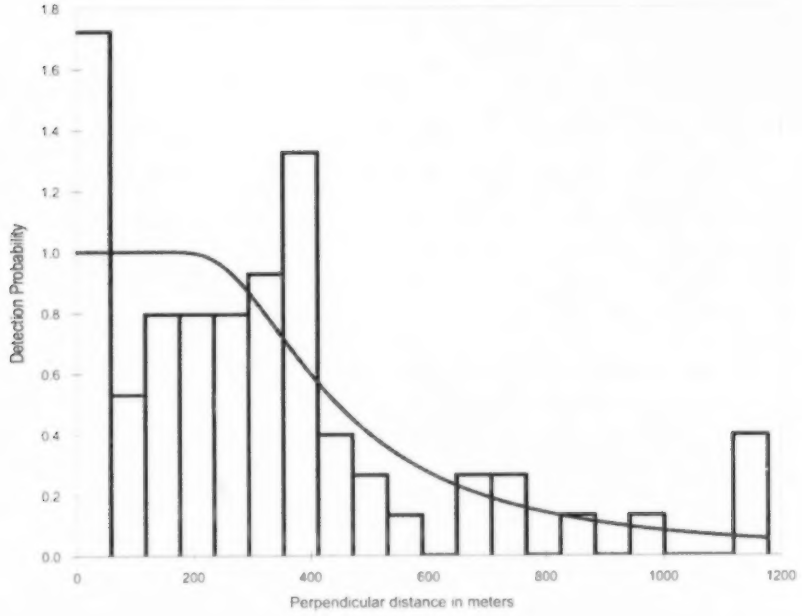

Figure 5. Distribution of all dolphins (common, Atlantic white-sided, and bottlenose dolphin) and harbour porpoises perpendicular distances from track-line during spring and summer, and the detection curve (hazard-rate) fitted on the untruncated 67 observations which provided an ESW of 523 m (95% CI: 402-680 m).

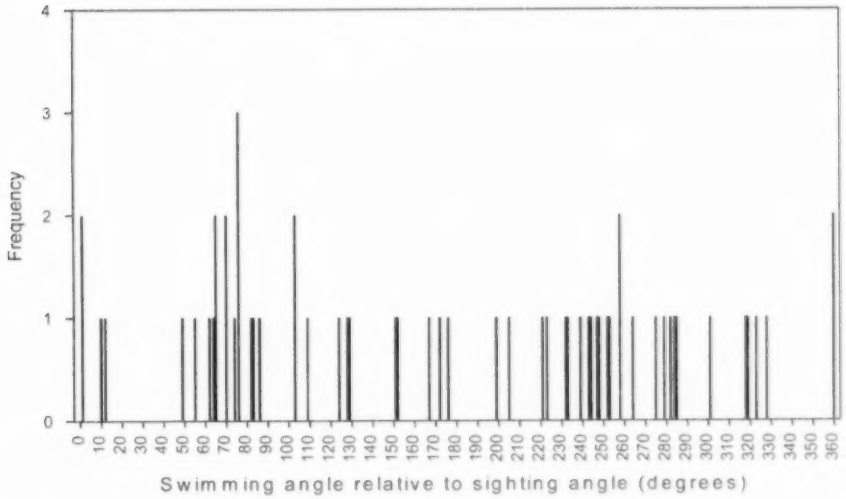

Figure 6. Swimming angle of dolphin groups relative to sighting angle. The 0° angle indicates that dolphins are swimming towards the vessel, 180° indicates that they are swimming away, and an angle of 90° indicates that the dolphins are swimming perpendicular to the sighting angle and showing their left side.

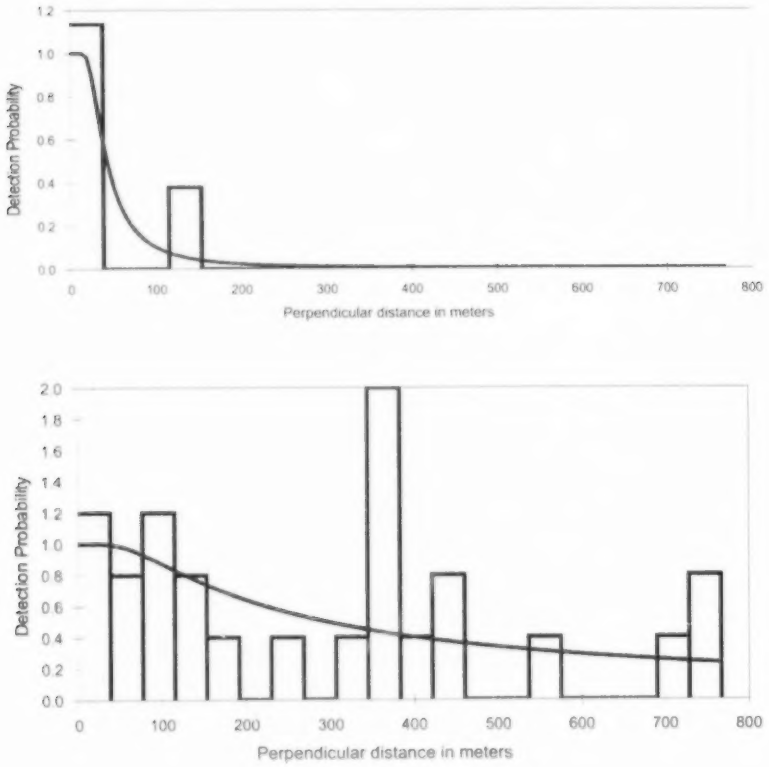

Figure 7. Distribution of minke whale perpendicular distances from track-line truncated at 767 m and the detection curve (hazard-rate) fitted separately on four observations in spring and 25 observations in summer that provided ESWs of 58 m (95% CI: 3-1112 m) and 383 m (95% CI: 157-936 m) respectively.

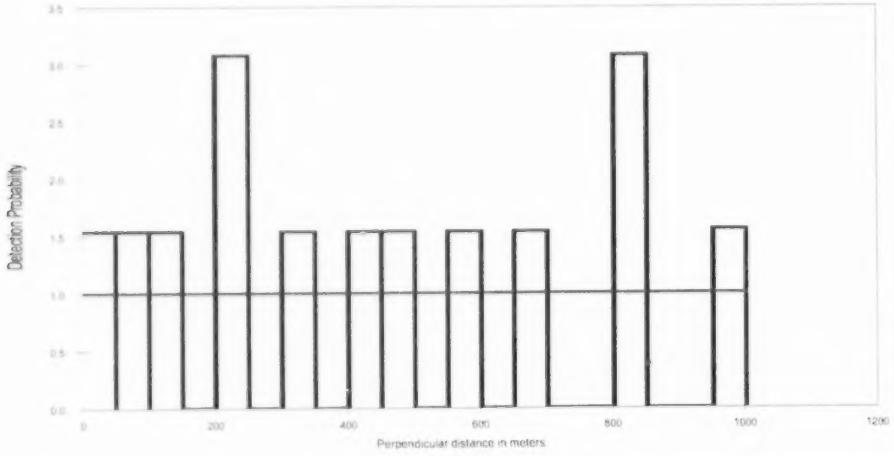

Figure 8. Distribution of the perpendicular distances from track-line data for the 13 groups of pilot whales sighted during spring and summer, with the uniform detection curve providing an ESW of 1002 m, the maximum perpendicular distance.

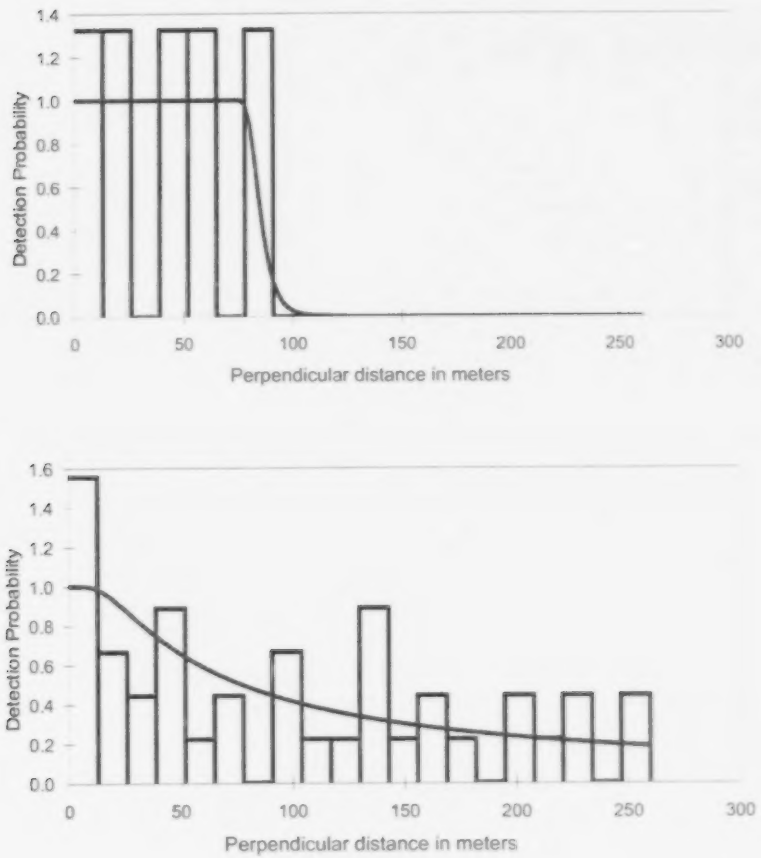

Figure 9. Grey seal perpendicular distances from track-line truncated at 260 m and the detection curve (hazard-rate) fitted separately on five observations in spring and 39 observation in summer that provided ESWs of 86 m (95% CI: 19-387 m) and 113 m (95% CI: 58-217 m), respectively.

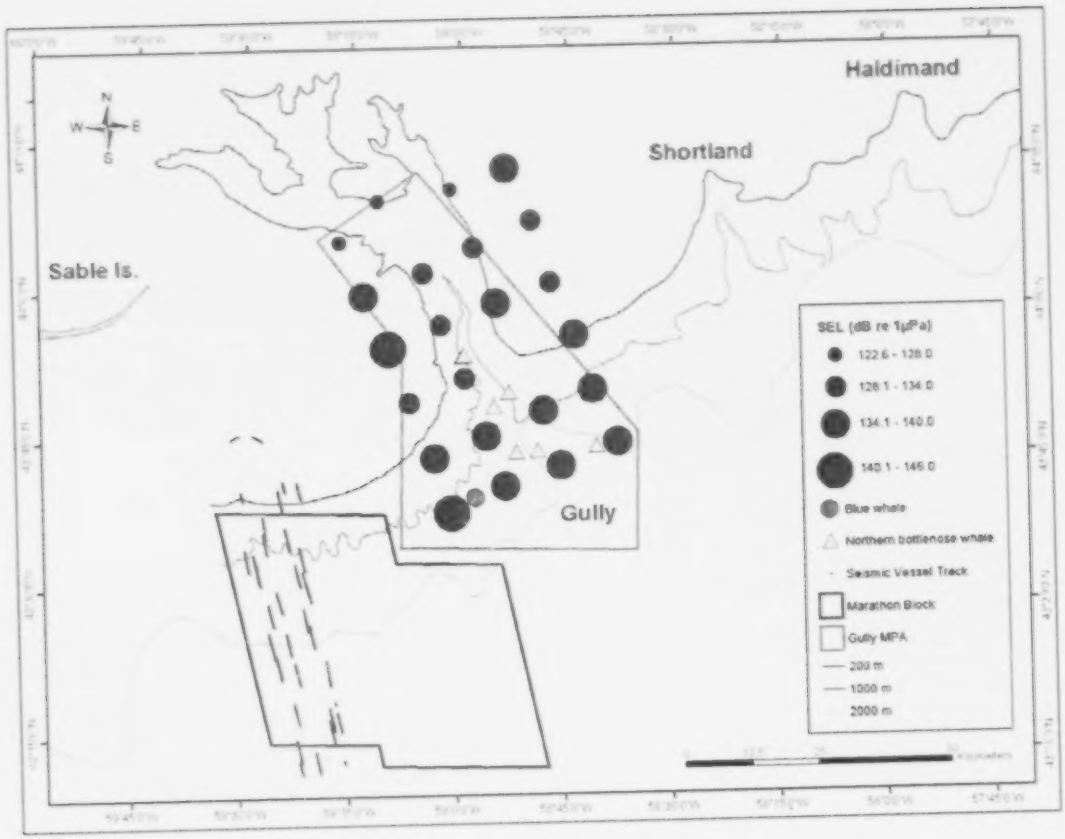

Figure 10. Received sound levels (SEL), locations of seismic source during acoustic measurements, and locations of sightings for NBWs and blue whales in the Gully, 2003 (Provided by Ian H. McQuinn, DFO, Mont-Joli).

APPENDIX 1. RATIONAL FOR A FIVE SAW-TOOTH TRANSECT LINE SURVEY

This survey design was established on the basis that the large 25 × 150 binoculars would be used for scanning for northern bottlenose whales as target species. The total length of survey lines required to produce a density estimate with a target CV of 20% (e.g., $CV_t(D)=0.20$) can be estimated using the following formula (Buckland *et al.* 2001):

$$L=[\, b \,/\, \{CV_t(D)\}^2 \,]\, [L_o / n_o] \qquad (1)$$

and then the expected number of sightings can be estimated using:

$$n=L\,(n_o/L_o) \qquad (2)$$

The unknown factor b should be estimated by a pilot survey, but it has been determined to be quite stable and a value of 3 has been determined to be conservative, *i.e.* this value would overestimate the required sample (Burham *et al.* 1980: 36). The factor n_o/L_o is the encounter rate that can be predicted by multiplying estimated values of density of groups of northern bottlenose whales in the Gully with the probability of detecting animals on the track-line (g_0), and twice the ESW estimated for proxies. Photo-identification work estimated that 44 (SE=6) northern bottlenose whales were present in the Gully at any given time in groups of three (mode ± SD: 3.04 ± 1.86) (Gowans *et al.* 2000, Gowans *et al.* 2001). This would represent a density of 0.024 group/km^2 for the 1851 km^2 planned survey area that includes the entire area most frequented by this species (Hooker *et al.* 2002c). Barlow (1999) modelled g_0 for long-diving whales for a team of two observers using 25 × 150 binoculars and a recorder in sea states of Beaufort 0 to 5. We used the estimate of $g_0=0.96$ for Baird's beaked whale, *Berardius bairdii*, which had the proportion of time at surface (23% of time) that was most similar to what has been reported for northern bottlenose in the Gully (30–38%: Hooker and Baird 1999). For ESW, we used 1.4 km (f(0)=0.614, truncation 3.7 km) estimated for small whales using 25 × binoculars in the Pacific (Barlow 1995). A total of 3431 km of lines would have been required to provide a $CV_t(D)=0.20$ for a survey using 25 × binoculars, which would have provided 75 sightings. In order to attain this objective, sets of 175 km zigzag lines covering the Gully would have had to be repeated 20 times, and would have required 185 hours of ship time at 18.5 km/h.